2.0 FIELD-DATA COLLECTION AND ANALYSIS OF SEDIMENT-TRANSPORT DATA

2.1 Introduction

Collection of field data was required to support several aspects of the research. Given that the research scope covered the entire basin, it was essential that as much information was collected first hand as possible to evaluate channel, upland, and sediment-transport conditions. Some of the data-collection activities such as ground reconnaissance and rapid geomorphic assessments (RGAs), as well as the GIS-based upland-erosion potential INDEX will be described in later sections as appropriate. This section concentrates on field work that was used to support numerical modeling, re-surveying of monumented historical, channel cross sections and computational techniques used in the analysis of suspended-sediment transport loadings.

2.2 Cross-Section Surveys

Ground surveys of channels were required for two main purposes:

(1) To provide input geometries of stream channels for the CONCEPTS channel-evolution model; and
(2) To compare previously surveyed locations with current (2002) conditions.

A total of 245 cross sections were surveyed in the Lake Tahoe Basin during a three-month data-collection campaign in the fall of 2002. Vertical-control surveys were conducted on General Creek (37 cross sections), Incline Creek (48 cross sections), Logan House Creek (21 cross sections), the Upper Truckee River (38 cross sections), and Ward Creek (44 cross sections). A vertical-control survey is a survey in which elevations are carried through a series of benchmarks (the majority of the benchmarks were not established, documented benchmarks). Detailed channel- geometry surveys were conducted at regularly spaced intervals along the channel, from a predetermined upper boundary (usually a major confluence) to the outlet at the lake, to provide input information for CONCEPTS or comparison with historic cross sections.

Historic cross-section information was available for Blackwood Creek (31 cross sections), Edgewood Creek (26 cross sections), General Creek (12 cross sections), Logan House Creek (11 cross sections), Ward Creek (8 cross sections), and the Upper Truckee River (33 cross sections). Because many of these cross sections had been last surveyed in 1987 it was not possible to re-locate all of the historical section monuments. Cross-section data for Blackwood Creek, Edgewood Creek, General Creek, and Logan House Creek were provided by K. Nolan (USGS, written communication, 2003). A. Stubblefield (U. California at Davis, written commun., 2002) provided location information and newly monumented cross-section information for Blackwood Creek and Ward Creek, and the Upper Truckee River cross-section information was provided by C. Walck (California State Parks, written commun., 2003).

2.3 Geotechnical Data for Analysis of Streambank Stability

The adjustment of channel width by mass-wasting and related processes represents an important mechanism of channel response and a potential major contributor to sediment loads in the Lake Tahoe Basin. In the loess area of the Midwest United States, for example, bank material contributes as much as 80% of the total sediment eroded from incised channels (Simon and Rinaldi, 2000). In the Lake Tahoe watershed, sediment entrained from bank failures are blamed as a major contributor to the sediment and lake-clarity problems affecting the lake.

Conceptual models of bank retreat and the delivery of bank sediments to the flow emphasize the importance of interactions between hydraulic forces acting at the bed and bank toe, and gravitational forces acting on *in situ* bank materials (Carson and Kirkby, 1972; Thorne, 1982; Simon *et al*., 1991). Failure occurs when erosion of the bank toe and the channel bed adjacent to the bank have increased the height and angle of the bank to the point that gravitational forces exceed the shear strength of the bank material. After failure, failed bank materials may be delivered directly to the flow and deposited as bed material, or dispersed as wash load, or deposited along the toe of the bank as intact blocks, or as smaller, dispersed aggregates (Simon *et al*., 1991). Analysis of streambank stability within CONCEPTS is based on measured field data using *in situ* devices such as the borehole shear test (Figure 2-1) and the submerged jet-test device (Figure 2-2).

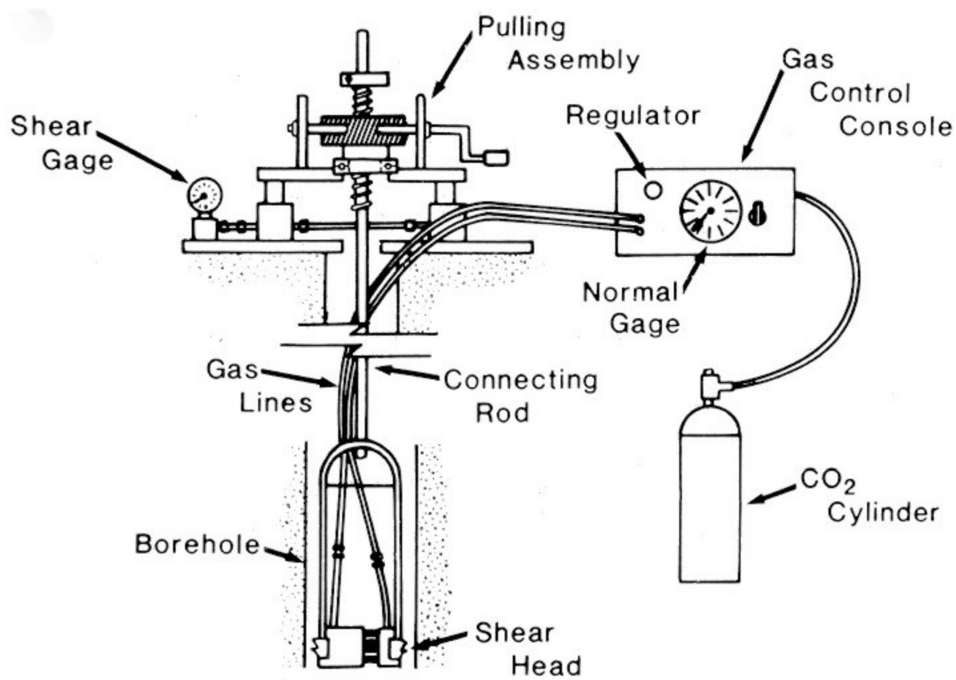

Figure 2-1. Schematic representation of borehole shear tester (BST) used to determine cohesive and frictional strengths of *in situ* streambank materials. Modified from Thorne *et al*., 1981.

2.3.1 Borehole Shear Testing and Bulk Unit Weights

To properly determine the resistance of cohesive materials to erosion by mass movement, data must be acquired on those characteristics that control shear strength; that is cohesion, angle of internal friction, pore-water pressure, and bulk unit weight. Cohesion and friction angle data can be obtained from standard laboratory testing (triaxial shear or unconfined compression tests), or by *in-situ* testing with a borehole shear-test (BST) device (Lohnes and Handy 1968; Thorne *et al.* 1981; Little *et al*. 1982; Lutenegger and Hallberg 1981). The BST provides, direct, drained shear-strength tests on the walls of a borehole (Figure 2-1). BST results for the General, Incline, Ward and Upper Truckee watersheds are shown in Tables 2-1 to 2-3. Advantages of the instrument include:

1. The test is performed *in situ* and testing is, therefore, performed on undisturbed material;
2. Cohesion and friction angle are evaluated separately with the cohesion value representing apparent cohesion (c_a). Effective cohesion (c') is then obtained by adjusting c_a according to measured pore-water pressure and ϕ^b.
3. A number of separate trials are run at the same sample depth to produce single values of cohesion and friction angle based on a standard Mohr-Coulomb failure envelope.
4. Data and results obtained from the instrument are plotted and calculated on site, allowing for repetition if results are unreasonable; and
5. Tests can be carried out at various depths in the bank to locate weak strata (Thorne *et al.* 1981).

Table 2-1. BST values obtained for General Creek.

Site name	River kilometer	Bank	Depth (m)	Material	c_a (kPa)	c' (kPa)	ϕ' (degrees)	Pore-water pressure (kPa)
56-36	0.30	Right	0.45	Sand/Silt	1.80	1.10	33.1	3.75
56-30	0.89	Right	0.45	Sand/Silt	6.50	2.90	21.9	20.7
56-23	2.20	Right	0.40	Sand/Silt	0.920	0.00	22.3	70.1
56-19	3.25	Right	0.45	Sand/Silt	2.40	0.00	14.8	68.1
56-17	3.60	Right	0.50	Sand/Silt	0.00	0.00	15.0	66.4
56-12	4.73	Right	0.45	Sand/Silt	6.28	1.30	21.7	57.2
56-06	5.90	Right	0.43	Sand/Silt	1.04	0.00	35.1	51.5
56-05	6.06	Right	0.32	Sand	8.09	1.00	33.0	50.5
56-03	6.50	Right	0.44	Sand/Silt	1.50	0.00	32.5	71.5

Table 2-2. BST values obtained for Incline Creek.

Site name	River kilometer	Bank	Depth (m)	Material	c_a (kPa)	c' (kPa)	ϕ' (degrees)	Pore-water pressure (kPa)
18-33	0.72	Left	0.45	Silt	0.00	0.00	35.8	54.0
18-32	0.85	Left	0.38	Silt	5.79	0.100	34.9	65.1
18-31	1.08	Right	0.45	Silt/Sand	14.5	6.00	26.6	48.3
18-10	4.53	Left	0.30	Silt/Sand	6.11	0.700	12.5	61.5
18-5	5.22	Left	0.40	Silt/Sand	0.00	0.00	21.1	2.30
18-2	5.61	Left	0.40	Silt/Sand	3.51	1.60	34.3	10.9

Table 2-3. BST values obtained for Ward Creek.

Site name	River kilometer	Bank	Depth (m)	Material	c_a (kPa)	c' (kPa)	ϕ' (degrees)	Pore-water pressure (kPa)
63-43	0.25	Right	0.70	Sand/Silt	0.00	0.00	32.2	68.6
63-39	0.78	Right	0.70	Sand/Silt	2.27	0.00	18.4	-
63-37	1.11	Left	0.35	Sand/Silt	0.00	0.00	31.5	50.7
63-33	1.42	Left	0.35	Sand/Silt	1.99	0.00	35.8	55.2
63-29	2.08	Left	0.40	Sand/Silt	0.00	0.00	33.1	68.6
63-21	3.64	Left	0.70	Sand/Silt	0.00	0.00	33.3	46.0
63-19	4.06	Left	0.40	Sand/Silt	0.65	0.00	35.0	65.8
63-14	5.12	Right	1.50	Silt	1.04	0.00	33.4	55.6
63-12	5.53	Right	0.80	Sand/Silt	3.09	0.500	33.6	59.1

2.4 Submerged Hydraulic Jet Testing: Erodibility of Fine-Grained Materials

The submerged jet-test device is used to estimate erosion rates due to hydraulic forces in fine-grained *in situ* materials (Hanson 1990; 1991; Hanson and Simon, 2001) (Figure 2-2). The device shoots a jet of water at a known head (stress) onto the streambed causing it to erode at a given rate. As the bed erodes, the distance between the jet and the bed increases, resulting in a decrease in the applied shear stress. Theoretically, the rate of erosion beneath the jet decreases asymptotically with time to zero. A critical shear stress for the material can then be calculated from the field data as that shear stress where there is no erosion.

The rate of erosion ε (m/s) is assumed to be proportional to the shear stress in excess of a critical shear stress and is expressed as:

$$\varepsilon = k\,(\tau_o - \tau_c)^{\,a} = k\,(\tau_e)^{\,a} \qquad (1)$$

where k = erodibility coefficient (m^3/N-s); τ_o = average boundary shear stress (Pa); τ_c = critical shear stress; a = exponent assumed to equal 1.0l and τ_e = excess shear stress (Pa). An inverse relation between τ_c and k occurs when soils exhibiting a low τ_c have a high k or when soils having a high τ_c have a low k. The measure of material resistance to hydraulic stresses is a function of both τ_c and k. Based on observations from across the United States, k can be estimated as a function of τ_c (Figure 2-3). This is generalized to:

$$k = 0.1\,\tau_c^{-0.5} \qquad (2)$$

Two jet tests were conducted at each site where cohesive bed or bank-toe material was present. In general, the average value of the two tests were used to represent the cross section and for input into CONCEPTS. Values for the Upper Truckee watershed are shown in Table 2-4.

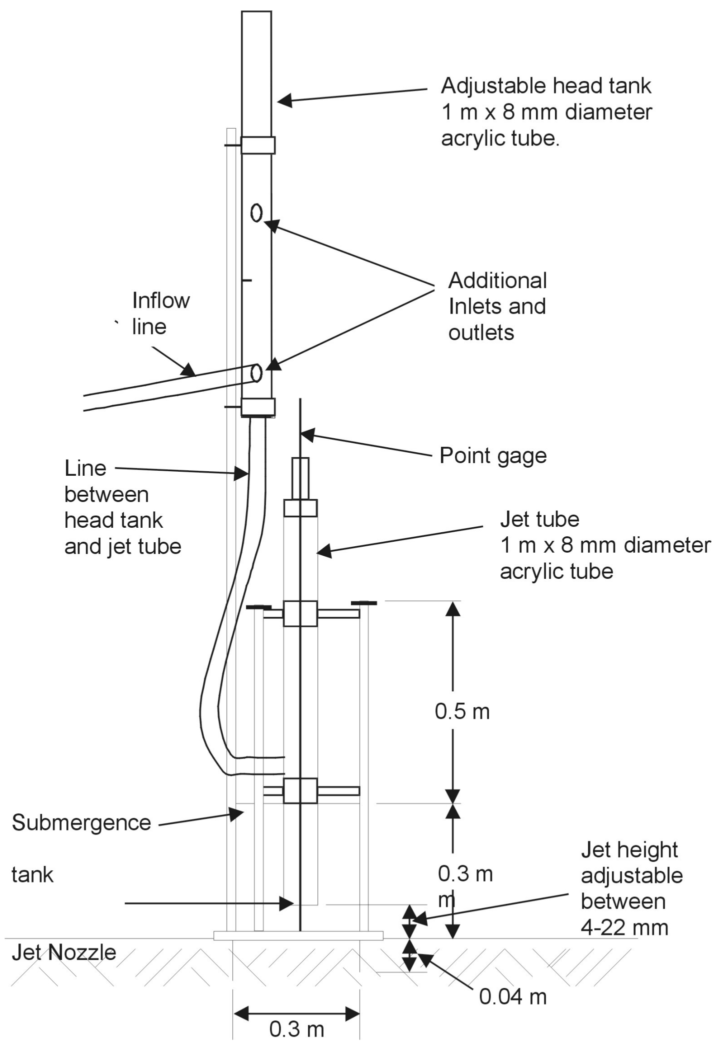

Figure 2-2. Schematic of submerged jet-test device used to measure the erodibility coefficient *k*, and the critical shear stress of fine-grained materials.

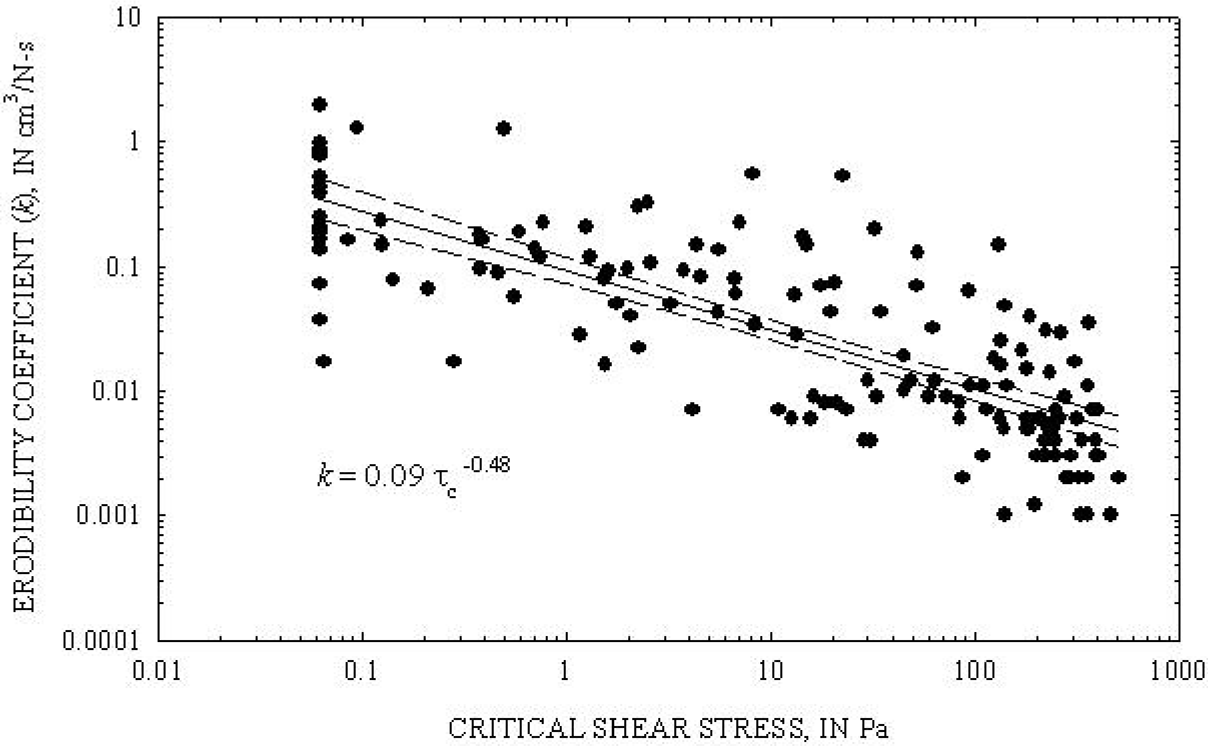

Figure 2-3. General relation between the erodibility coefficient *k*, and critical shear stress τ_c for fine-grained materials based on hundreds of jet tests from across the United States (Hanson and Simon, 2001).

Table 2-4. BST and submerged jet-test values obtained for the Upper Truckee River.

Site name	River kilometer	Bank	Depth (m)	Material	c_a (kPa)	c' (kPa)	ϕ' (degrees)	Pore-water pressure (kPa)	Jet location	τ_c (Pa)	k (cm^3/N-s)
44-110	1.56	Left	0.60	Silt Clay	7.95	2.20	37.6	65.5	-	-	-
44-92	2.94	Left	1.00	Sandy Silt	0.772	0.00	36.8	25.2	LBface	5.24	2.76
44-92	2.94	-	-	-	-	-	-	-	LBtoe	1.92	4.24
44-87	4.51	Right	0.30	Sand	0.160	0.00	31.0	4.30	-	-	-
44-85	5.06	Right	0.90	Silt	1.21	0.00	31.1	72.1	LBtoe	0.390	5.65
44-85	5.06	-	-	-	-	-	-	-	LBface	0.500	13.5
44-78	7.14	Left	0.35	Silt	4.20	0.90	32.5	75.7	-	-	-
44-75	8.46	Right	1.00	Silty Sand	3.30	2.60	27.4	4.20	RBtoe	0.280	29.6
44-75	8.46	-	-	-	-	-	-	-	RBface	0.360	4.87
44-68	10.8	Right	0.20	Silt	5.67	0.70	6.58	57.1	RBtoe	0.611	11.7
44-43	13.1	Right	1.15	Silty Sand	4.20	1.20	21.8	69.0	RBtoe	1.65	7.98
44-43	13.1	-	-	-	-	-	-	-	RBface	0.991	11.7

44-39	13.5	Right	0.30	Sandy Silt	0.230	0.00	30.5	70.4	RBtoe	1.15	12.5
44-39	13.5	-	-	-	-	-	-	-	RBface	1.29	16.8
44-26	14.8	Right	0.40	Sandy Silt	3.84	0.600	31.0	73.5	RBface	0.104	14.9
44-20	17.8	Left	0.40	Sandy Silt	1.77	0.00	18.8	39.5	LBface	1.49	4.28
44-20	17.8	-	-	-	-	-	-	-	LBtoe	0.0160	28.3
44-15	19.9	Left	0.89	Silty Sand	3.17	1.00	31.0	25.2	LBtoe	0.400	27.9
44-12	20.7	Right	1.10	Silty	2.38	0.00	28.7	73.4	LBface	0.78	29.0
44-04	23.0	Right	0.40	Silt	2.84	0.60	31.0	51.1	RBtoe	1.65	4.71

2.4.1 Bank-Toe Erodibility

In watersheds including Ward, General, Logan House, Edgewood, Blackwood, Incline and Upper Truckee, *in situ* bank-toe materials are composed predominantly of sands inter-mixed with cohesive material, gravel and cobbles. As with determining the erodibility of cohesive streambed materials, a submerged jet-test device (modified to operate on inclined surfaces) was used to determine values of τ_c and *k*. Values for sites in the Upper Truckee are shown in Table 2-4. Erosion of bank-toe materials is then calculated using an excess shear stress approach. For coarse-grained materials, bulk samples were obtained for particle-size analysis. Critical shear stress of these types of materials can then be calculated using conventional techniques as a function of particle size and weight.

2.5 <u>Texture of Bank and Bed Materials</u>

Fine-grained sediment is one of the main concerns in the Lake Tahoe area because of the nature of fine sediment to remain in suspension for longer periods of time and degrade lake clarity. Although alluvial materials are dominated by materials of sand size and coarser, fine-grained sediments can be found in varying quantities in streambanks. This sediment is released from the banks when the banks fail. To determine where bank failures were occurring, rapid geomorphic assessments were conducted across the watershed and bulk samples of bank material were collected at each of these sites. The purpose of this was for users of this report to be able to correlate the occurrence of bank failures with the relative proportion of fine sediments delivered by those bank failures not only for the seven intensely studied streams, but in the remainder of the watersheds as well.

The spatial distribution of fine-grained streambank materials, expressed as percent finer than 0.062 mm is illustrated in Figure 2-4. Values ranged from 0 to about 27 %, with the lower reaches of the Upper Truckee River having the greatest volume of fine-grained materials in its banks and an average fine-grained content of 14%. Ward Creek had the highest average concentration of fines, 17%. The average composition of fine-grained bank material for each of the intensely studied watersheds is shown in Table 2-5. Fine-grained materials were not found in measurable quantities on channel beds.

Table 2-5. Average percentage of fine-grained material contained in the banks of each modeled watershed.

Stream	Number of samples	Silt plus clay (%)
Upper Truckee	62	14
Ward	44	17
General	46	10
Edgewood	4	2
Blackwood	13	6
Incline	63	5

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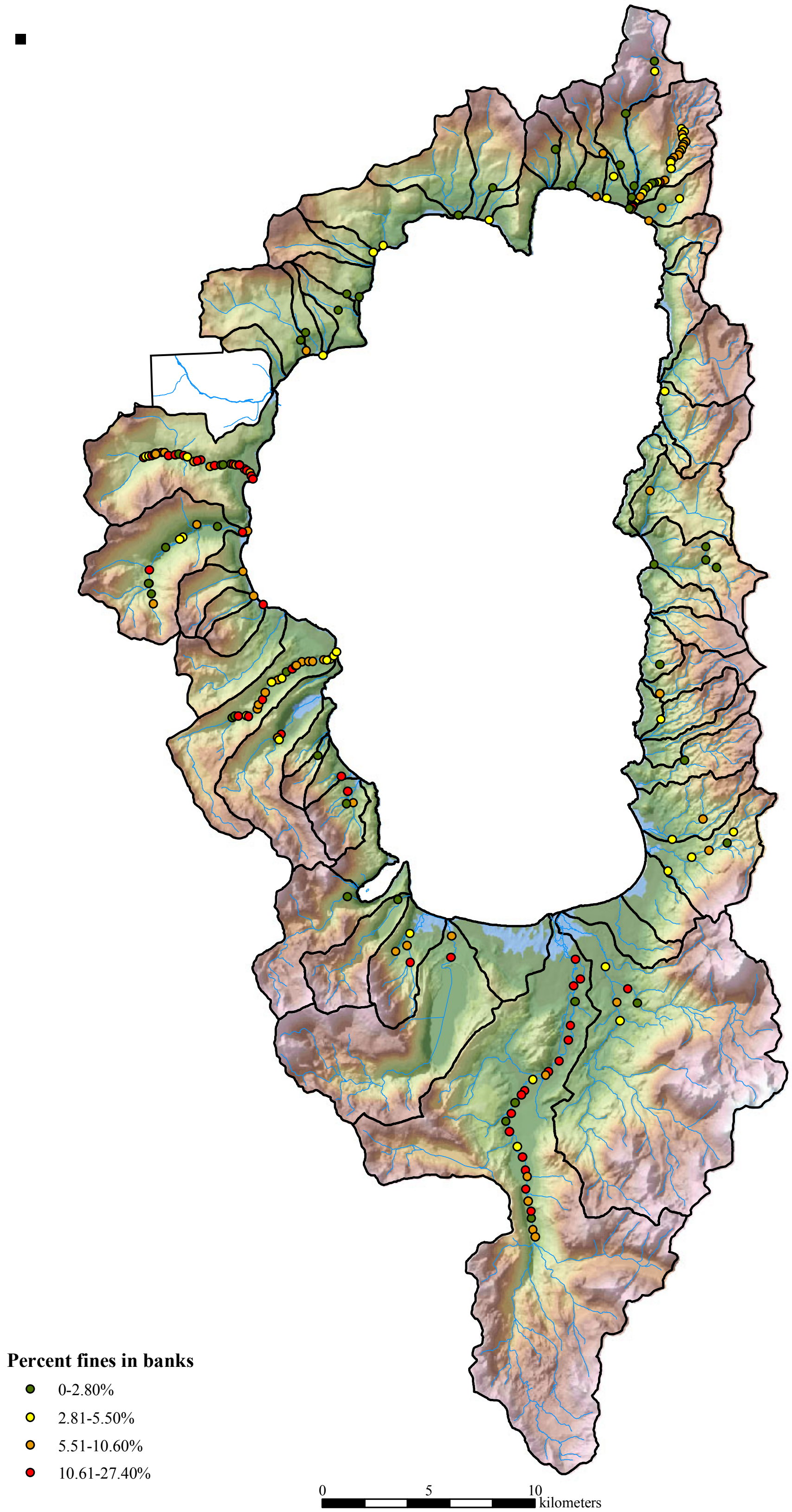

Figure 2-4. Spatial distribution of fine-grained bank materials.

CONCEPTS requires information on sediment texture to determine sediment routing and sorting processes. Bulk samples of bed materials were collected at the survey and RGA sites to be analyzed in the laboratory for particle-size distributions. If the bed was dominated by gravel-sized and boulder-sized material a count of a minimum of 100 particles was made to determine the distribution of particle sizes. In cases where streambeds were composed of a bi-modal mixture of sediment sizes with coarser-grained gravels, cobbles and boulders, particle-size distributions were weighted by the percentage of the bed covered by each type of sample (ie. bulk and particle count). Bed-material particle-size distributions for each cross section in each of the modeled watersheds is shown in Appendix B. The total number of particle-size samples for each stream is shown in Table 2-6.

Table 2-6. Total number of particle-size samples taken for each stream.

Stream	**Total number of samples taken**		
	Bed	**Bank toe**	**Bank (internal and bank face)**
Upper Truckee	31	28	62
Ward	32	17	44
General	27	7	46
Edgewood	14	0	5
Blackwood	10	0	13
Incline	35	0	63
Logan House Creek	3	0	0

Most study sites in the Lake Tahoe Basin area are characterized by streambeds composed of sand, gravel and cobbles (Appendix B). Resistance of these non-cohesive materials is a function of bed roughness and particle size (weight), and is expressed in terms of a dimensionless critical shear stress (Shields 1936):

$$\tau^* = \tau_o / (\rho_s - \rho_w)\, g\, D \qquad (3)$$

where τ^* = critical dimensionless shear stress; ρ_s = sediment density (kg/m^3); ρ_w = water density (kg/m^3); g = gravitational acceleration (m/s^2); and D = characteristic particle diameter (m). Average boundary shear stress (τ_o) is the drag exerted by the flow on the bed and is defined as:

$$\tau_o = \gamma_w R S_b \qquad (4)$$

where γ_w = unit weight of water (N/m^3); and R = hydraulic radius (area/wetted perimeter)(m). Critical shear stress (τ_c) in dimensional form can be obtained by invoking the Shields criterion and, for hydrodynamically rough beds, utilizing a value of 0.06 for τ^*.

$$\tau_c = 0.06\, (\rho_s - \rho_w)\, g\, D \qquad (5)$$

Thus, the shear stress required to entrain a grain of diameter *D* can be estimated. Other commonly used values of τ^* are 0.03 and 0.047 (Vanoni 1957). CONCEPTS uses 13 particle-size classes to analyze entrainment and sorting of non-cohesive sediment by invoking the Shields' criteria (Equations 3 and 5).

2.6 Generation of Suspended-Sediment Rating Relations

2.6.1 Introduction

Suspended sediment loads originating from watersheds draining to Lake Tahoe have been shown to be a principal cause of increased turbidity. Therefore, calculation of river suspended loads for different Lake Tahoe watersheds will provide a clear indication of problematic watersheds contributing to the reduced clarity in the lake observed over previous decades (Figure 1-1).

A function of the USGS, Water Resources Division is to collect continuous flow data supplemented by water-quality sample data at thousands of river gauging stations nationwide. The watersheds that drain to Lake Tahoe contain numerous gauging stations, albeit with differing periods of record and availability of water-quality data. One of the water quality parameters sampled on a regular basis is concentration of suspended sediment. When used in conjunction with the instantaneous discharge at sample collection, this sample data can be utilized to compute suspended-sediment transport rates. Integration with continuous flow records allows suspended-sediment loads contributed into the Lake Tahoe basin to be estimated.

2.6.2 Data Sources

Gauged suspended sediment and flow data were acquired from several sources. Instantaneous suspended-sediment concentration with associated instantaneous flow data for 38 (USGS) gauging stations within the Lake Tahoe Basin were downloaded from the USGS web site. Additional gauging-station data for Edgewood, Glenbrook, Dollar, Quail Lake, Eagle, Meeks, Burke and Wood Creeks, and various road gutters (within Grass Lake Creek, Eagle Creek, Meeks Creek and Quail Lake Creek watersheds) were obtained from tables in several reports, outlined in Table 2-7.

Table 2-7. Sources other than USGS Web sites with suspended-sediment data.

Watershed name	Data source
Edgewood Creek (including some additional data USGS 10336756)	Garcia (1988)
Glenbrook Creek (including some additional data for USGS 10336730)	Glancy (1977)
Dollar Creek	Kroll (1976)
Quail Lake Creek	Kroll (1976)
Eagle Creek	Kroll (1976)
Meeks Creek	Kroll (1976)
Burke Creek	LTBMU (2003)
Wood Creek	Glancy (1988)
Road Gutters (within Grass Lake Creek, Eagle Creek, Meeks Creek and Quail Creek watersheds)	Kroll (1974)

Data availability ranged considerably between gages. Of the twenty six gages with mean- daily flow data, the duration varied from 2.6 years (10336756, Edgewood Creek Tributary) to 41.0 years (10336660: Blackwood Creek and 10336780: Trout Creek). The number of instantaneous suspended-sediment concentration measurements with associated discharges also varied from single figures for several gages (Highway Gutter gages and temporary gages on Glenbrook Creek), to 824 records (10336698: Third Creek). Again, the relation between discharge and sediment can be assessed more accurately for gages with larger datasets, covering a greater duration and containing a more varied range of discharges.

2.6.3 Methods

From the available data, suspended-sediment rating relations were generated for the 68 gaging stations listed in Table 2-8. Scattergraphs in log-log space were generated to examine the correlation firstly between:

(1) suspended-sediment concentration (in mg/l) and discharge (in meters cubed per second; m^3/s), and

(2) load (in tonnes per day ;T/d) and discharge.

The latter was used for subsequent total load and yield calculations. A daily load was calculated for each sample using the following formula:

$$L = 0.0864\, C\, Q \qquad (6)$$

where: L = load in T/d;
C = instantaneous concentration, in mg/l; and
Q = instantaneous discharge, in m^3/s.
The value 0.0864 is to convert from seconds to days and from milligrams to tonnes.

Linear regression in log-log space results in power function describing the relation between instantaneous discharge and load as:

$$L = a\, Q^{\,b} \qquad (7)$$

where a and b are regression coefficients.

In cases where there was substantial departure of data from the regression line in a consistent direction, a single power equation was not sufficient to adequately represent the relation. In these cases, either two- or three-linear segments (separate rating equations) were developed for designated flow ranges. The division point between these data ranges was identified by eye, and a manual iterative procedure was carried out to ensure the division point was optimal. Figures 2-5 and 2-6 contain examples of a two- and three-section rating curve, respectively.

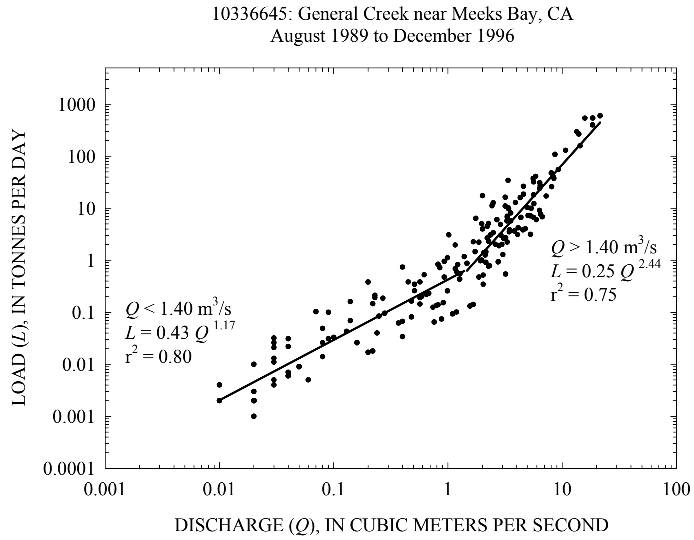

Figure 2-5. Example of two-section suspended-sediment rating relation.

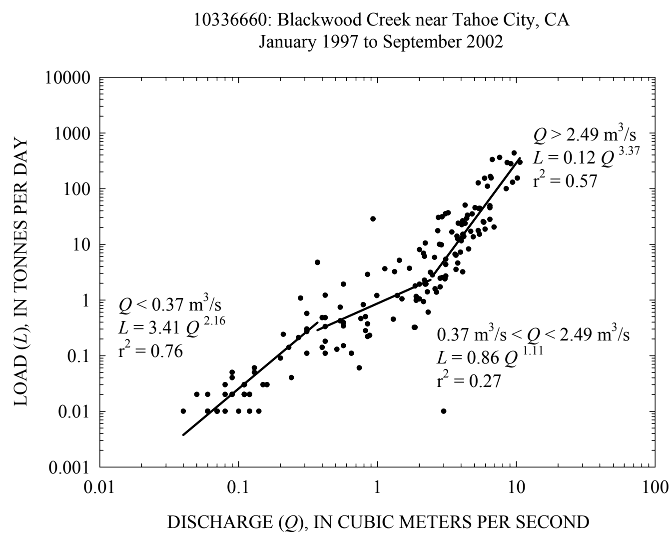

Figure 2-6. Example of three-section suspended-sediment rating relation.

2.6.4 Effect of the January 1997 Rain on Snow Event

Over the 1st and 2nd January 1997, a major rain on snow event occurred in the Lake Tahoe basin, generating the highest peak flows observed in the record period for some gauging stations. To test the effects of this large runoff event on suspended-sediment transport characteristics prior to and following January 1, 1997 sample data were separated throughout the basin into pre-event and post-event datasets and the regression process was repeated. The same methodology described above was adopted to produce the most accurate set of regression equations for each dataset. Plots of the pre- and post-event transport ratings were superimposed enabling comparison of the slopes and intercepts of the regression lines. Examination of these graphs indicated that suspended-sediment transport rates were consistently lower across the range of discharges for many stations following the January 1997 storm event. An example is shown in Figure 2-7.

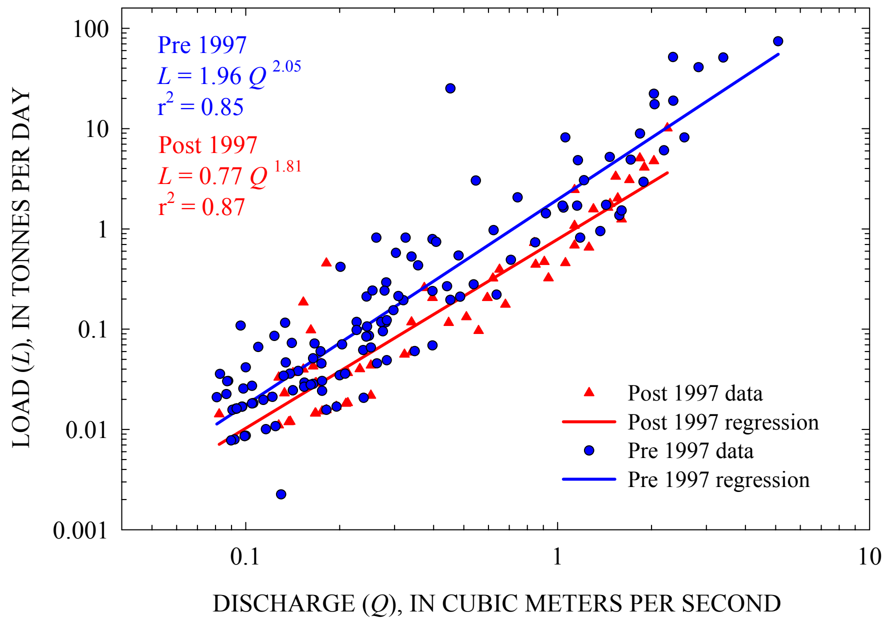

Figure 2-7. Pre and post January 1997 suspended-sediment rating curve: 10336770.

Statistical analyses were used to determine whether the observed lower slope and/or intercept of the post-1997 suspended-sediment ratings were significantly different. Firstly, a Type I sum of squares test was carried out to determine if the slopes of the pre- and post-suspended sediment rating equation were equal to zero. Secondly, a type III test was run to ascertain whether the slopes of the two relations were equal to each other. Finally, an additional type III test was conducted to determine if the intercepts of the two regression lines were equal. Appendix C contains pre-Jan 1997 and post-Jan 1997 suspended-sediment rating curves for all Lake Tahoe gauging stations, and other sites.

2.6.5 Analysis of Shifts in Transport Ratings

For stations with greater than ten years of sample data and a sufficient number of samples, separate rating relations were generated for three to five approximately equal time periods to ascertain whether the relation between discharge and transport rate showed any temporal variation. Rating relations for each station and for each period were plotted on the same axes for each station for ease of comparison. Shifts to a higher load at a given discharge over the range of discharges indicate that suspended-sediment loads are increasing. The reverse is true for identifying decreasing loads.

2.7 <u>Suspended-Sediment Loads</u>

2.7.1 Total Suspended-Sediment Load Calculations

Mean-daily flow data were available for 26 of the USGS gaging stations where sufficient data were available to construct sediment-transport ratings. Data were downloaded from a USGS web site and discharge units were converted to m^3/s. Daily loads were calculated for each gage by applying the appropriate rating equation (ie. pre or post 1997 event) to the mean discharge for each day, giving a total suspended load in T/d. These values were summed by month and by calendar year for validation of the AnnAGNPs and CONCEPTS models and to test for spatial and temporal variations in suspended-sediment transport throughout the Lake Tahoe Basin.

Because of the potential error in extrapolating log-log transport curves beyond their measured bounds, the maximum mean-daily flow was compared with the maximum sampled discharge used to generate the regression equation (Table 2-9). The ratio of maximum daily flow to maximum sampled flow was calculated for each rating of a given gage, and in most cases it was below one. This procedure reduced the risk of introducing error due to the suspended-sediment rating being extrapolated beyond the data used to generate it. On occasions where the maximum mean-daily flow was greater than the maximum sampled flow (post 1997 event data, where only a few years of samples were available), the pre-event rating for that gage was utilized, as this extended to discharges of sufficient magnitude. Table 2-10 summarizes this data.

2.7.2 Fine-Load Calculations

Percentages of fine (<0.062mm) and coarse suspended sediment (>0.062mm) was available for sixteen of the USGS gaging stations with mean-daily flow. Seventeen additional gaging stations possessed percent fine and coarse suspended-sediment data, but had no continuous flow record (Table 2-11).

Using the total load and percent finer for each sample, the fine load and coarse load for each sample was calculated. Separate fine and coarse load scattergraphs and regression curves were generated using this information. Due to substantial data scatter, the total load estimated by the regression equation in comparison to the sum of the fine and coarse loads predicted by the new regression equations often deviated. Therefore, an alternative approach was adopted. The percent fine sediment was plotted against discharge and best-fit lines were added through a trial-and-error approach. Appendix D contains these plots. Using the mean-daily flow record, total load regression equations, and the percent fine suspended-sediment graphs, daily loads in tonnes finer than 0.062mm were calculated. These were summed to provide monthly and annual values.

2.7.3 Suspended-Sediment Yield Calculations

Previous analysis provided absolute magnitudes of suspended-sediment loads discharged from various Lake Tahoe watersheds. However, with watersheds areas varying between 1.61 km^2 (Bliss Creek) and 147 km^2 (Upper Truckee River), it is almost inevitable that the larger drainage basins will contribute higher loads. Therefore, loads were divided by the watershed area to ascertain suspended-sediment yields ($T/d/km^2$) in order to make a fair comparison of the relative suspended-sediment contributions from different parts of the basin. The area of land upstream from each station was obtained from USGS metadata files. Annual and monthly suspended-sediment yields were subsequently calculated for each station by dividing the load for a given period by the watershed area.

2.7.4 Recurrence Interval of the January 1997 Event

For each of the stations with calculated load data, the day with the highest sediment load was identified for each calendar year having a complete record of mean-daily flows. For most stations, the maximum-daily load occurred during the peak snowmelt period between April and June. The loads on these dates were used to create an annual maximum series and generate a magnitude-frequency curve using the log-Pearson III distribution (Riggs, 1968).

Table 2-8. Summary of suspended-sediment transport data used to generate rating relations. Note: n = number of samples.

Station	Years of flow record	Period of flow record	n	Period of sampling record	Years of record	Rating ?	Pre/Post 1997 Ratings?	Coarse/ Fine Ratings ?
10336760	8.0	10/1/92-9/30/00	251	8/20/92-9/13/02	10.1	Y	Y	-
10336756	2.8	1/1/81-9/30/83	67	4/12/91-4/27/01	10.0	Y	Y	-
103367592	10.9	11/18/89-9/30/00	516	11/2/89-9/13/02	12.8	Y	Y	-
10336696	-	-	34	10/16/69-7/6/70	0.7	Y	-	-
10336690	-	-	51	10/15/69-9/22/70	0.9	Y	-	-
10336670	4.0	10/1/72-9/30/76	37	4/23/73-8/14/76	3.3	Y	-	Y
10336660	41.0	10/1/60-9/30/01	483	5/16/74-8/19/02	28.3	Y	Y	Y
10336698	31.0	10/1/69-9/30/00	824	10/15/69-9/16/02	32.9	Y	Y	Y
10336676	29.0	10/1/72-9/30/01	495	12/20/72-9/19/02	30.0	Y	Y	Y
10336694	-	-	155	10/15/69-8/5/02	32.8	Y	Y	-
10336645	21.3	7/7/80-9/30/01	189	4/30/81-9/19/02	21.4	Y	Y	Y
10336593	3.0	10/1/71-9/30/74	70	5/8/72-6/28/74	2.1	Y	-	Y
10336692	-	-	81	4/11/91-9/5/01	9.4	Y	Y	-
103366092	10.3	6/1/90-9/30/00	287	8/29/89-9/12/02	13.1	Y	Y	-
10336700	31.0	10/1/69-9/30/00	662	10/15/69-9/16/02	32.9	Y	Y	Y
10336674	10.0	10/1/91-9/30/01	256	3/5/91-9/19/02	11.5	Y	Y	-
10336750	17.0	10/1/83-9/30/00	106	8/23/89-8/2/02	13.0	Y	Y	-
10336610	30.0	10/1/71-9/30/01	451	11/4/72-9/12/02	29.8	Y	Y	Y
10336580	10.4	5/12/90-9/30/00	290	8/30/89-9/12/02	13.1	Y	Y	-
10336790	21.0	10/1/71-9/30/92	296	3/4/72-9/11/02	30.5	Y	Y	Y
10336688	-	-	156	10/15/69-8/5/02	32.8	Y	Y	-
10336675	10.0	10/1/91-9/30/01	214	9/1/89-9/20/01	12.0	Y	Y	-
103366965	-	-	83	8/17/89-9/5/00	11.1	Y	Y	-
10336770	10.4	5/22/90-9/30/00	210	11/2/89-9/11/02	12.8	Y	Y	-
103366958	-	-	84	8/17/89-9/6/01	12.1	Y	Y	-
10336780	41.0	10/1/60-9/30/01	110	11/9/73-6/28/02	28.6	Y	-	Y
103366995	10.8	12/28/89-9/30/00	307	8/15/89-9/16/02	13.1	Y	Y	Y
103366993	10.4	5/1/90-9/30/00	314	11/1/89-9/16/02	12.8	Y	Y	Y
103366997	-	-	111	8/17/89-8/6/02	13.0	Y	Y	-
10336673	-	-	155	4/30/73-5/18/70	3.1	Y	-	-
103367585	11.0	10/1/89-9/30/00	280	8/22/89-7/18/02	12.9	Y	Y	Y
10336691	-	-	84	4/11/91-12/8/00	9.6	Y	Y	-
10336765	3.5	4/12/89-9/30/92	83	8/17/89-9/5/00	11.1	Y	Y	Y
10336735	-	-	100	4/12/91-8/1/02	11.3	Y	Y	-

10336775	10.3	6/1/90-9/30/00	289	4/24/89-9/11/02	13.4	Y	Y	-
10336730	29.0	10/1/71-9/30/00	562	10/18/71-9/13/02	30.2	Y	Y	Y
10336725	-	-	88	8/18/89-9/700	11.1	Y	Y	-
10336740	17.0	10/1/83-9/30/00	339	5/10/84-9/13/02	18.3	Y	Y	Y
39-2	-	-	63	3/13/1990-8/17/92	2.5	Y	-	-
39-3	-	-	79	3/17/93-7/2/98	5.5	Y	Y	-
39-4	-	-	14	3/13/90-9/6/90	0.5	Y	-	-
39-7	-	-	117	3/28/91-7/2/98	7.5	Y	Y	-
39-8	-	-	30	3/17/93-5/11/98	5.3	Y	Y	-
28 PL 3.38	-	-	36	10/12/72-4/26/73	0.5	Y	-	Y
28 PL 3.50	-	-	44	11/4/72-4/14/73	0.4	Y	-	Y
89 ED 1.70	-	-	57	4/4/73-5/10/73	0.1	Y	-	Y
89 ED 1.94	-	-	158	10/20/72-8/4/73	0.8	Y	-	Y
89 ED 2.11	-	-	48	10/20/72-6/6/73	0.6	Y	-	Y
89 ED 2.21	-	-	68	10/18/72-6/6/73	0.6	Y	-	Y
89 ED 2.44	-	-	161	10/18/72-9/27/73	0.9	Y	-	Y
89 ED 2.99	-	-	62	12/19/72-5/31/73	0.4	Y	-	Y
89 ED 4.37	-	-	126	10/1/72-6/11/73	0.7	Y	-	Y
89 ED 4.45	-	-	49	11/4/72-5/31/73	0.6	Y	-	Y
89 ED 16.61	-	-	78	10/18/72-5/31/73	0.6	Y	-	Y
89 ED 16.87	-	-	89	11/4/72-8/17/73	0.8	Y	-	Y
89 ED 24.49	-	-	11	1/16/73-4/13/73	0.2	Y	-	Y
89 ED 24.65	-	-	4	1/16/73-4/11/73	0.2	Y	-	Y
89 ED 25.44	-	-	2	1/15/73-1/16/73	0.0	Y	-	Y
89 PL 1.27	-	-	25	11/4/72-5/30/73	0.6	Y	-	Y
89 PL 1.42	-	-	36	12/21/72-5/18/73	0.4	Y	-	Y
10336757	-	-	57	11/13/81-5/24/83	2.3	Y	-	-
10336758	-	-	83	2/12/1981-5/24/83	2.3	Y	-	-
Site A	-	-	9	11/11/71-7/9/74	2.7	Y	-	-
Site D	-	-	41	11/11/71-7/9/74	2.7	Y	-	-
Site E	-	-	4	11/11/71-5/6/74	2.5	Y	-	-
Site G	-	-	7	11/11/71-7/9/74	2.7	Y	-	-
Site H	-	-	6	3/7/72-5/6/74	2.2	Y	-	-
Site I	-	-	2	11/11/71-3/7/72	0.2	Y	-	-

Table 2-9. List of number of rating relations and sections used to calculate daily, monthly, and annual suspended-sediment transport rates.

Stream	Station	Data Period		Pre / Post 1997 data available ?	Number of Rating Sections: Pre 1997	Number of Rating Sections: Post 1997
		Flow	Suspended Sediment			
Blackwood	10336660	10/1/60-9/30/01	5/16/74-8/19/02	Y	3	3
Eagle Rock	103367592	11/18/89-9/30/00	11/2/89-9/13/02	Y	1	1
Edgewood	103367585	10/1/89-9/30/00	8/22/89-7/18/02	Y	1	2
Edgewood	10336765	4/12/89-9/30/92	8/17/89-9/5/00	Y	2	0
Edgewood	10336760	10/1/92-9/30/00	8/20/92-9/13/02	Y	1	1
Edgewood Trib.	10336756	1/1/81-9/30/83	4/12/91-4/27/01	Y	1	1
General	10336645	7/7/80-9/30/01	4/30/81-9/19/02	Y	2	2
Glenbrook	10336730	10/1/71-9/30/00	10/18/71-9/13/02	Y	1	2
Grass Lake	10336593	10/1/71-9/30/74	5/8/72-6/28/74	N	1	0
Incline	103366995	12/28/89-9/30/00	8/15/89-9/16/02	Y	1	1
Incline	103366993	5/1/90-9/30/00	11/1/89-9/16/02	Y	1	2
Incline	10336700	10/1/69-9/30/00	10/15/69-9/16/02	Y	1	1
Logan House	10336740	10/1/83-9/30/00	5/10/84-9/13/02	Y	2	2
Third	10336698	10/1/69-9/30/00	10/15/69-9/16/02	Y	1	1
Trout	10336790	10/1/71-9/30/92	3/4/72-9/11/02	Y	1	0
Trout	10336780	10/1/60-9/30/01	11/9/73-6/28/02	N	1	1
Trout	10336775	6/1/90-9/30/00	4/24/89-9/11/02	Y	1	1
Trout	10336770	5/22/90-9/30/00	11/2/89-9/11/02	Y	1	1
UTR	103366092	6/1/90-9/30/00	8/29/89-9/12/02	Y	2	2
UTR	10336610	10/1/71-9/30/01	11/4/72-9/12/02	Y	1	1
UTR	10336580	5/12/90-9/30/00	8/30/89-9/12/02	Y	2	2
Ward	10336676	10/1/72-9/30/01	12/20/72-9/19/02	Y	2	2
Ward	10336675	10/1/91-9/30/01	9/1/89-9/20/01	Y	2	1
Ward	10336674	10/1/91-9/30/01	3/5/91-9/19/02	Y	2	2
Ward	10336670	10/1/72-9/30/76	4/23/73-8/14/76	N	1	0

Table 2-10. Pre-1997 suspended-sediment rating relations calculated from measured instantaneous flow and concentration data.

Stream	Station	Rating Relations					
		Eq. 1	**Eq. 1 limit**	**Eq. 2**	**Eq. 2 limit**	**Eq. 3**	**Eq. 3 limit**
		(T)	**(m^3/s)**	**(T)**	**(m^3/s)**	**(T)**	**(m^3/s)**
Blackwood	10336660	$L = .07Q^{1.48}$	$Q < 1.47$	$L=1.15Q^{2.09}$	$1.47 < Q < 10.62$	$L =1.35Q^{2.18}$	$Q > 10.6$
Eagle Rock	103367592	$L = 9.3Q^{1.82}$	All flows				
Edgewood	103367585	$L = 2.8Q^{1.70}$	All flows				
Edgewood	10336765	$L=.900Q^{1.20}$	$Q < .116$	$L = .27Q^{1.90}$	$Q > 0.116$		
Edgewood	10336760	$L=3.29Q^{1.84}$	All flows				
Edgewood Trib.	10336756	$L =1.39Q^{1.31}$	All flows				
General	10336645	$L =.430Q^{1.17}$	$Q < 1.40$	$L =.248Q^{2.44}$	$Q >1.40$		
Glenbrook	10336730	$L =2.23Q^{1.34}$	All flows				
Grass Lake	10336593	$L =1.53Q^{1.80}$	All flows				
Incline	103366995	$L =7.01Q^{1.68}$	All flows				
Incline	103366993	$L =3.37Q^{1.61}$	All flows				
Incline	10336700	$L =26.6Q^{2.19}$	All flows				
Logan House	10336740	$L =1.35Q^{1.32}$	$Q <0.038$	$L= 30.3Q^{2.16}$	$Q > 0.038$cms		
Third	10336698	$L =38.6Q^{2.01}$	All flows				
Trout	10336790	$L =1.23Q^{1.61}$	All flows				
Trout	10336780	$L =2.27Q^{1.87}$	All flows				
Trout	10336775	$L =1.03Q^{1.86}$	All flows				
Trout	10336770	$L =1.96Q^{2.04}$	All flows				
UTR	103366092	$L =.213Q^{1.28}$	$Q < 3.00$	$L =.141Q^{2.05}$	$Q >3.00$		
UTR	10336610	$L =.991Q^{1.55}$	All flows				
UTR	10336580	$L =.253Q^{1.33}$	$Q < 2.00$	$L =.135Q^{2.22}$	$Q >2.00$		
Ward	10336676	$L =1.26Q^{1.43}$	$Q < 2.00$	$L =.404Q^{2.69}$	$Q >2.00$		
Ward	10336675	$L =.642Q^{1.33}$	$Q < 3.71$	$L =.094Q^{3.14}$	$Q >3.71$		
Ward	10336674	$L =.792Q^{1.38}$	$Q < 1.40$	$L =.543Q^{2.54}$	$Q >1.40$		
Ward	10336670	$L =6.92Q^{2.10}$	All flows				

Table 2-11. Post-1997 suspended-sediment rating relations calculated from measured instantaneous flow and concentration data.

Stream	Station	Rating Relations					
		Eq. 1	Eq. 1 limit	Eq. 2	Eq. 2 limit	Eq. 3	Eq. 3 limit
		(T)	(m^3/s)	(T)	(m^3/s)	(T)	(m^3/s)
Blackwood	10336660	$L=3.41Q^{2.16}$	Q < 0.37	$L=.865Q^{1.11}$	0.37 < Q < 2.49	$L = 0.12Q^{3.37}$	Q > 2.49
Eagle Rock	103367592	$L=.701Q^{1.05}$	All flows				
Edgewood	103367585	$L=1.43Q^{1.37}$	Q < 0.096	$L=86.6Q^{3.10}$	0.4 > Q > 0.096	Pre 1997 eq 3	Q >0.400
Edgewood	10336765						
Edgewood	10336760	$L=1.32Q^{1.57}$	All flows				
Edgewood Trib.	10336756	$L=23.2Q^{2.02}$	All flows				
General	10336645	$L=.703Q^{1.48}$	Q < 2.00	$L=.232Q^{2.93}$	Q > 2.00		
Glenbrook	10336730	$L=0.54Q^{1.08}$	Q < 0.085	$L=0.27Q^{1.60}$	Q > 0.085		
Incline	103366995	$L=4.24Q^{1.92}$	All flows				
Incline	103366993	$L=.477Q^{1.28}$	Q < 0.20	$L=10.8Q^{3.15}$	Q > 0.2		
Incline	10336700	$L=3.70Q^{1.86}$	All flows				
Logan House	10336740	$L=1.37Q^{1.39}$	Q < 0.060	$L = 118Q^{3.09}$	Q > 0.060s		
Third	10336698	$L=4.09Q^{1.94}$	All flows				
Trout	10336780	$L=2.27Q^{1.87}$	All flows				
Trout	10336775	$L=.562Q^{1.81}$	All flows				
Trout	10336770	$L=.774Q^{1.81}$	All flows				
UTR	103366092	$L=.169Q^{1.25}$	Q < 0.351	$L=.029Q^{2.64}$	0.351 < Q < 20.0	Pre 1997 eq 2	Q > 20.0
UTR	10336610	$L=.784Q^{1.33}$	All flows				
UTR	10336580	$L=.170Q^{1.23}$	Q < 2.40	$L=.054Q^{2.48}$	Q > 2.40		
Ward	10336676	$L=.58Q^{1.41}$	Q < 2.00	$L=.158Q^{2.98}$	2.00 < Q < 16.0	Pre 1997 eq 2	Q > 16.0
Ward	10336675	$L=.691Q^{1.62}$	All flows				
Ward	10336674	$L=.330Q^{1.27}$	Q < 1.50	$L=.411Q^{2.38}$	Q > 1.50		

2.8 General Description of AGNPS Modeling Technology

The Agricultural Non-Point Source Pollutant (AGNPS) watershed simulation model (Bingner and Theurer, 2001a) has been developed as a tool for use in evaluating the pollutant loadings within a watershed and the impact farming and mixed-use activities have on pollution control. Various modeling components have been integrated within AGNPS to form a suite of modules. Each module provides information needed by other modules to enhance the predictive capabilities of each. The modules in AGNPS critical to the Lake Tahoe watershed simulation study include: (1) AnnAGNPS Version 3.30 (Cronshey and Theurer, 1998), a watershed-scale, continuous-simulation, pollutant loading computer model designed to quantify & identify the source of pollutant loadings anywhere in the watershed for optimization & risk analysis; and, (2) Conservational Channel Evolution and Pollutant Transport System (CONCEPTS) (Langendoen, 2000), a set of stream network, corridor, & water quality computer models designed to predict & quantify the effects of bank erosion & failures, bank mass wasting, bed aggradation & degradation, burial & re-entrainment of contaminants, and streamside riparian vegetation on channel morphology and pollutant loadings.

The Annualized Agricultural Non-Point Source Pollutant loading model (AnnAGNPS) is an advanced technological watershed evaluation tool, which has been developed through a partnering project with the United States Department of Agriculture – Agriculture Research Service (USDA-ARS) and Natural Resources Conservation Service (NRCS) to aid in the evaluation of watershed response to agricultural management practices. Through continuous simulation of surface runoff, sediment and chemical non-point source pollutant loading from watersheds, the impact of BMPs on TMDLs can be evaluated for risk and cost/benefit analyses.

AnnAGNPS is a continuous simulation, daily time step, pollutant loading model and includes significantly more advanced features than the single-event AGNPS 5.0 (Young et al., 1989). Daily climate information is needed to account for the temporal variation in the weather. The spatial variability of climate can be included by assigning appropriate climate records to specific locations within the watershed. The spatial variability within a watershed of soils, landuse, and topography, is accounted for by dividing the watershed into many homogeneous drainage areas. These simulated drainage areas are then integrated together by simulated rivers and streams, which route the runoff and pollutants from each individual homogeneous area to downstream. From individual fields, runoff can be produced from precipitation events that include rainfall, snowmelt and irrigation. A daily soil water balance is maintained, so runoff can be determined when a precipitation event occurs. The erosion within each field is predicted based on the technology incorporated from the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997). The model can be used to examine the effects of implementing various conservation alternatives within a watershed such as alternative cropping and tillage systems including the effects of fertilizer, pesticide, irrigation application rate as well as point source yields and feedlot management (Bosch et al., 1998).

2.8.1 Input Data Requirements

As part of the input data preparation process there are a number of component modules that support the user in developing the needed AnnAGNPS databases. These include: (1) the TOpographic PArameteriZation program (TOPAZ) (Garbrecht and Martz, 1995), to generate cell and stream network information from a watershed digital elevation model (DEM) and provide all of the topographic related information for AnnAGNPS. A subset of TOPAZ, TOPAGNPS, is the set of TOPAZ modules used within AGNPS. The use of the TOPAGNPS generated stream network is also incorporated by CONCEPTS to provide the link of where upland sources are entering the channel and then routed downstream; (2) The AGricultural watershed FLOWnet generation program (AGFLOW) (Bingner et al., 1997; Bingner et al., 2001b) is used to determine the topographic-related input parameters for AnnAGNPS and to format the TOPAGNPS output for importation into the form needed by AnnAGNPS; (3) The Generation of weather Elements for Multiple applications (GEM) program (Johnson et al., 2000) is used to generate the climate information for AnnAGNPS if historical climate is not used; (4) The program Complete Climate takes the information from GEM and formats the data for use by AnnAGNPS, along with determining a few additional parameters; (5) A graphical input editor that assists the user in developing the AnnAGNPS database (Bingner et al., 1998); (6) A visual interface program to view the TOPAGNPS related geographical information system (GIS) data (Bingner et al., 1996); (7) A conversion program that transforms a single event AGNPS 5.0 dataset into what is needed to perform a single event simulation with AnnAGNPS and, (8) An

Arcview program to facilitate the use of Items 1-7. There is an output processor that can be used to help analyze the results from AnnAGNPS by generating a summary of the results in tabular or GIS format.

2.8.2 Contributions from Cells Adjacent to the Main Channel

Loading information to the main channel for use with CONCEPTS is obtained by routing the AnnAGNPS water and sediment discharged by each AnnAGNPS cell through the channel system. At the outlet of each tributary that flows into the main channel AnnAGNPS provides: the flow; sediment by particle sizes of clay, silt, and sand; peak discharge; and, the time of concentration as part of an output file that can be used as an input file into CONCEPTS. This information is used in routing water and sediment by CONCEPTS in the main channel. All tributary channels in each of the Lake Tahoe watersheds simulated by AnnAGNPS is assumed to be stable and therefore not eroding. Although, sediment in transport can be deposited within the tributaries before reaching the main channel simulated by CONCEPTS.

2.8.3 Contributions from Tributaries into the Main Channel

The discharges from the tributaries provide the link between AnnAGNPS cells and CONCEPTS for the water and sediment that does not flow directly into the main channel. There are also AnnAGNPS cells that are along the main channel and deposit water and sediment directly into the main channel. These AnnAGNPS cells are also simulated and provide discharge information to CONCEPTS through an AnnAGNPS output file.

2.9 General Description of CONCEPTS Modeling Technology

CONCEPTS simulates unsteady, one-dimensional flow, transport of cohesive and cohesionless sediments in suspension and on the bed selectively by size class, and bank erosion processes in stream corridors (Langendoen 2000). Hence, it can predict the dynamic response of flow, sediment transport and channel form (‘channel evolution’) to disturbances including channelization, altered hydrologic regime (e.g. by dam construction or urbanization), or instream hydraulic structures.

2.9.1 Hydraulics

CONCEPTS assumes stream flow to be one-dimensional along the centerline of the channel. It computes the flow as a function of time simultaneously at a series of cross sections along the stream using the Saint Venant equations. The governing equations are discretized using the generalized Preissmann scheme, and the resulting set of algebraic equations are solved using Gaussian elimination with partial pivoting for banded matrices. Four types of hydraulic structures are included in CONCEPTS: box and pipe culverts, bridge crossings, grade control (drop) structures, and any structure for which a rating curve is available.

2.9.2 Sediment transport and bed adjustment

CONCEPTS calculates total-load sediment transport rates by size fraction from a mass conservation law, and taking into account the differing processes governing entrainment and deposition of cohesive and cohesionless bed material (Langendoen 2000). CONCEPTS handles particle sizes ranging from clay to cobbles. For graded bed material, the sediment transport rates depend on the bed material composition, which itself depends on historical erosion and deposition rates. CONCEPTS divides the bed into a surface or active layer and a subsurface layer. These layers constitute the so-called 'mixing layer'. Sediment particles are continuously exchanged between the flow and surficial layer, whereas particles are only exchanged between the surface layer and substrate when the bed scours and fills. For cohesive materials, the erosion rate is calculated by an excess shear-stress approach while the deposition rate is based on particle settling velocity.

2.9.3 Streambank Erosion

CONCEPTS simulates channel width adjustment by incorporating the fundamental physical processes responsible for bank retreat: (1) fluvial erosion or entrainment of bank toe material by flow, and (2) bank mass failure due to gravity (Langendoen 2000). Natural streambank material may be cohesive or noncohesive and may comprise numerous soil layers reflecting the depositional history of the bank materials; each layer can have physical properties quite different from those of other layers. CONCEPTS accounts for streambank stratigraphy by allowing variable critical shear-stresses to be assigned to the bank materials. An average shear-stress on each soil layer is computed, which increases with depth. Because of the resulting shear stress distribution, CONCEPTS is able to more realistically simulate streambank erosion caused by undercutting and cantilever failures.

Bank stability is analyzed via the limit equilibrium method, based on static equilibrium of forces and/or moments. Streambank failure occurs when gravitational forces that tend to move soil downslope exceed the forces that resist movement. The risk of failure is usually expressed by a factor of safety, defined as the ratio of resisting to driving forces or moments. CONCEPTS performs stability analyses of planar slip failures and cantilever failures of overhanging banks by dividing the bank into slices, and evaluating the balance of forces on each slice in vertical and horizontal directions. The slope of the failure surface is defined as that slope for which the factor of safety is a minimum. The bank's geometry, soil shear-strength (effective cohesion, c', and angle of internal friction, ϕ'), pore-water pressure, confining pressure, and riparian vegetation determine the stability of the bank.

2.9.4 Input Data Requirements

Typical CONCEPTS input data are: water and sediment inflow at the upstream boundary of the model channel and any tributaries; the geometry (cross sections) of the channel; Manning's *n* roughness coefficients; and composition of bed and bank material. In addition, the user needs to supply bank-material properties for the streambank erosion component of CONCEPTS, such as the critical shear stress required to entrain bank-material particles, and the shear-strength parameters effective cohesion, c', and angle of internal friction, ϕ'.